In-situ and Land-Based Remote Sensing of River Inlets and Their Interaction with Coastal Waters: Mouth of Columbia River

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LONG-TERM GOALS

Principal research goals are to characterize the physics and fluid dynamics which exist at the Mouth of the Columbia River. Coming from the relatively benign environment of the New River Inlet (RIVET I), this DRI will provide much stronger flows, larger waves, and more dynamic signals for our remote sensing instruments to observe. A by-product of the observational program will be the development of sensing capabilities that may have Naval interest.

OBJECTIVES

Our interests for this project span the fields of surface waves, coastal oceanography, and remote sensing. Our oceanographic objectives are to characterize the spatial gradients of surface waves and wave breaking within the mouth of the Columbia River, measure the time-varying nature of horizontal and vertical structure of the currents, and examine how the waves are modulated by these currents. From a remote sensing perspective, we desire to understand how to interpret vessel and shore-based HH polarized radar backscatter in regions of strong gradients for purposes of extracting oceanographic variables. Remote sensing data will be enhanced and validated using in-situ meteorological (MET) buoys and drifting miniature GPS wave buoys.

APPROACH

Our approach to this area of research was to implement an array of observations at the study site. Our principal platform of operation was to be the R/V Thompson, however due to last minute repairs, we had to mobilize the R/V Thompson out of the University of Washington. This substitute ship was more than adequate to conduct the research as it: a) is a large vessel, b) has a crew experienced in the navigating the Pacific Northwest, c) it is equipped with dynamic positioning to allow it to hold station for conducting fixed radar studies of the sea surface; and d) it is large enough to accommodate other scientists. We were fortunate enough to be able to equip the R/V Thompson with an X-Band radar and data acquisition system that will be dedicated to science and left on board for future use. We temporarily equipped the ship with a 5 point laser altimeter/IMU system on the bow (Figure 1) to measure sea surface height, directional wave spectra, and ship motion. As the laser altimeter system was funded under other ONR

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funds (ESMF Program), we had remove it and install it on the R/V Thompson for that demonstration project.

Figure 1. 5-point laser altimeter system being mounted on the R/V Thompson (left), with its structural integrity being put to the test going over the Columbia River Bar! (right)

The R/V Thompson conducted its radar operations from the "at sea" position looking inland toward the river mouth, and the "upriver" position, looking out the river mouth towards the incoming wind and waves. Both positions were used during the two-week deployment, with continuous X-band radar operations collecting data with up to a 5 km footprint, wind and backscatter strength permitting. Additionally, the Thompson will be used to deploy and retrieve the MET buoys, and the miniature drifting GPS wave buoys.

The mobility of the R/V Thompson was complemented by a van-mounted, shore-based radar, that had previously been deployed in RIVET I (Figure 2). The location of the radar van is on the southwestern-most point of the river mouth. We sampling at 7.5 m range resolution, 1024 range sample, for over 7.5 km of coverage (wind, waves, and backscatter permitting), which was the largest data range we've ever collected. With ample winds, we hoped to span the over 6 km breadth of the Colombia River mouth. The van ran autonomously for roughly a 48-hour period through the use of solar panels in the day and a gasoline generator at night. However, we typically serviced the van daily to ensure uninterrupted operations. In addition to fueling the generator, data drives from the on board RAID array were swapped out and copied to ensure data integrity.

Figure 2. SIO RadarVan operating at the Clatsop Spit, South Jetty, Ft. Stevens State Park, OR

The miniature wave buoys were deployed on a day to day basis. When the R/V Thompson was in a good position, and the tide and river flow where deemed suitable for deployment, we launched (usually) 5 buoys. The swift flow at the river mouth took some getting used to. Our first deployments upriver found the wave buoys moving at high speeds toward the river mouth, only to be dashed on the rock jetties! Sometimes they ended up on the north jetty, sometimes the south jetty. We worked it out after a few trials, so that the buoys would cross the bar, and eventually exit the river mouth and end up in the open ocean to be recovered at the end of the day's work. Other times they hooked around the north jetty and ended up on the beach. Definitely a dynamic environment.

Figure 3. Miniature wave buoys after being deployed (left), ending up on the jetty (center), and on the beach (right)

The MET buoys were moored at roughly 3 km intervals from just inside the river mouth, going further out to sea. This was to ensure a good measurement of the surface weather conditions over the entire radar and buoy operations area. Unfortunately, due to the extremely strong ebb and flow of the tides and currents at the MCR, the MET buoys were submerged and inoperable for most of the experiment.

WORK COMPLETED

SIO RadarVan radar data collected continously from 5/22 – 6/6, 2013, 1024 range samples at 7.5 meter range resolution, 1/12 degree angular resolution. Total volume collected - 6.7TB.

R/V Thompson radar data collected continuously from 5/24 – 6/6, 2013, 1024 range samples at 5 meter range resolution, 1/12 degree angular resolution. Total volume collected - 6.2TB.

R/V Thompson 5-point bow laser system data collected continuously from 5/24 – 6/6, 2013, 10 Hz sampling of bow heave, laser range to sea surface. Total volume collected – 17GB. Laser 5 (port side) had a failure from 5/30 at 2300 UTC – 5/31 at 1800 UTC, was taken down and repaired for the rest of the cruise.

R/V Thompson mini wave buoy deployments on 5/29 through 6/4, 2 Hz sampling of 3-axis GPS velocities, directional wave spectra, course and speed over ground, SST.

R/V Thompson CTD casts and ADCP data collected at random intervals.

Quality assurance and quality control (QA/QC) is currently being performed on all data.

RESULTS

Data processing is still in it's preliminary stage, but some simple initial results are available. In Figure 4, an example of a typical day of radar coverage is show. The larger diameter radar image comes from the RadarVan on shore, and the remaining three smaller diameter scans come from the R/V Thompson transiting back and forth across the MCR.

**Figure 4 – Typical SIO X-Band radar coverage**

A simple, yet interesting processing technique for finding fronts in and around the MCR is backscatter averaging. By removing the range dependent backscatter mean value (detrending) and then taking one minute averages of those images, one can easily see fronts and track them over time. Figure 5 shows a visible front off the bow of the R/V Thompson, and a backscatter average showing a similar front.
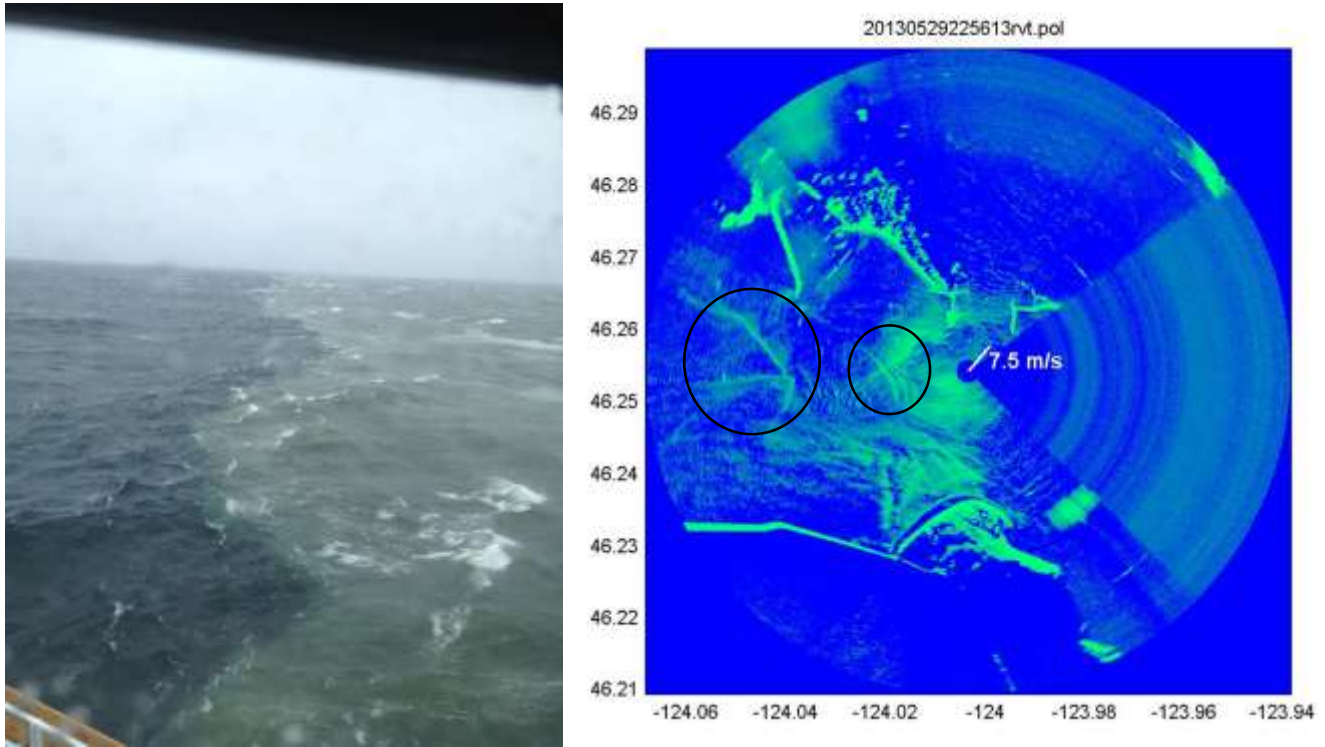

Figure 5. A visible front off of the R/V Thompson (left), and a backscatter average showing multiple similar fronts (right)

A more compled form of backscatter analysis comes from the SIO phase resolving wave inversion software (previously employed in ONR programs HiRes and RIVET I). This process performs a 3D spectral band pass filter which detects, filters, and inverts back to (x,y,z,t) space to provide phase resolved dispersive wave maps of the ocean surface. As is especially the case with the MCR, the dispersive waves are shifted by tides, currents, fronts, and bathymetry. Figure 6 shows the R/V Thompson heading out over the bar, with an example of the wave inversion. The heightened wave activity over the bar, and with an ebbing tideal flow, is apparent. These are the waves hitting the bow of the R/V Thompson in previous Figure 1.
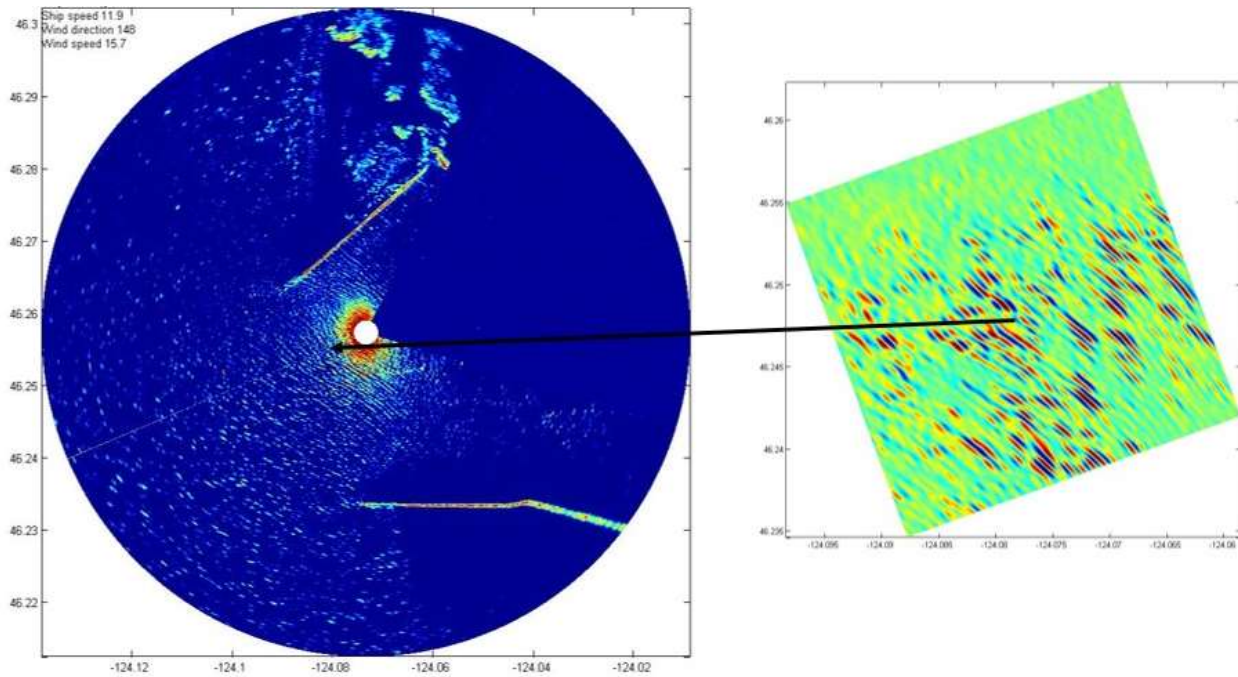
Figure 6. Backscatter from the R/V Thompson while transiting over the bar at ebbing tide (left), and the associated phase resolved wave field

When the wave buoys successfully made it out the river inlet, they provided measurements of the currents, the wave field, and the interaction between the two. Figure 7 shows a typical track as the buoys went out to see. The yellow arrows are indicating wave direction.
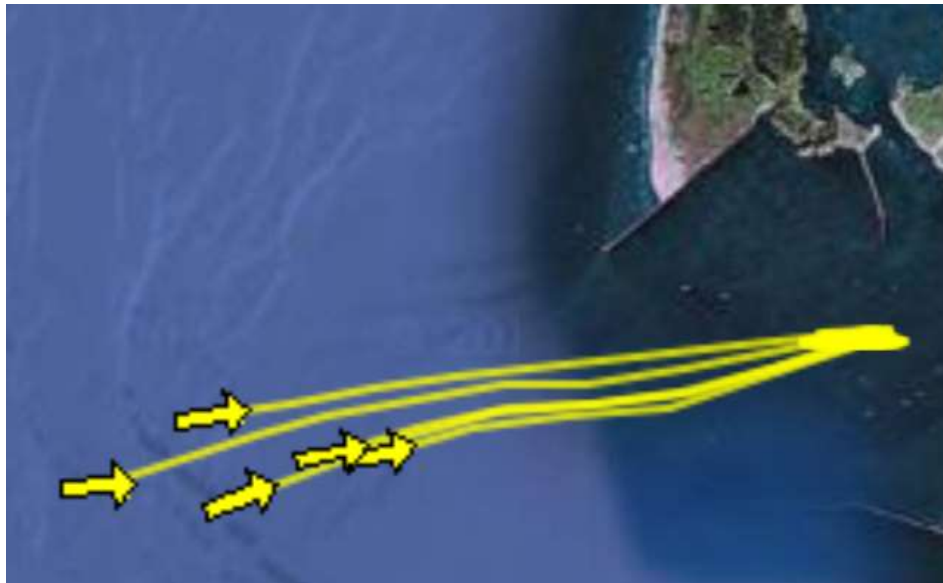

Figure 7. Typical miniature wave buoy tracks with wave direction indicated by yellow arrows

Figure 8 shows the variation in current shear near the mouth of the river during ebb and flood tides. We hope to use this data as ground truth to compare to the X-Band radar derived currents.
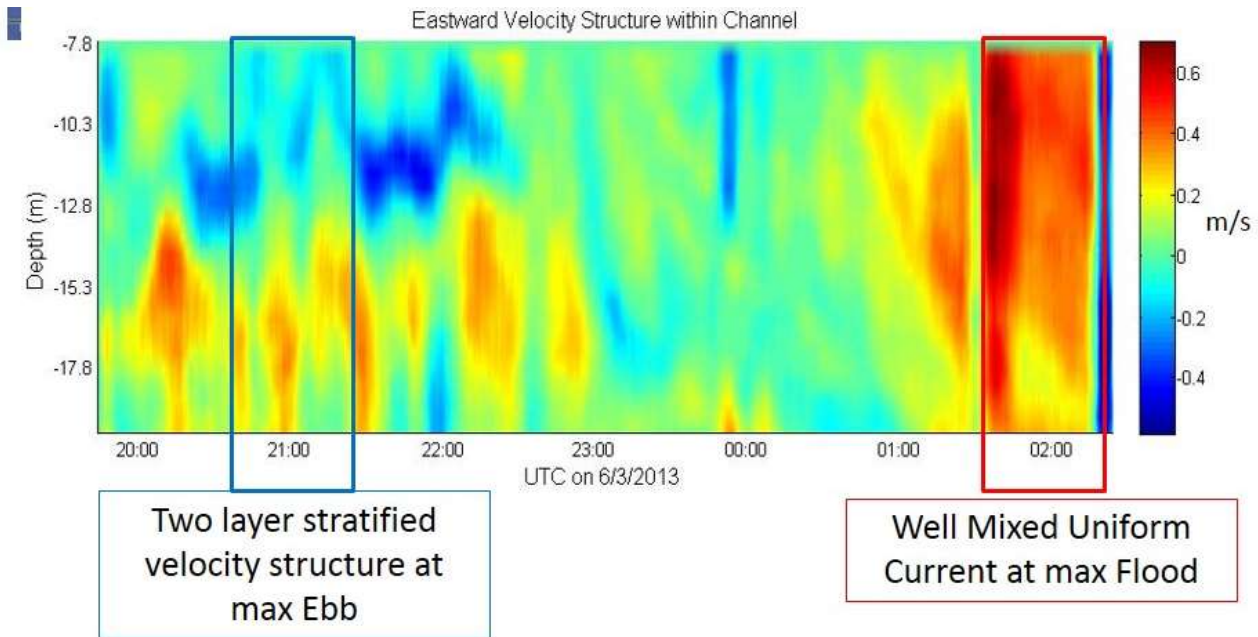
Figure 8. R/V Thompson ADCP Measurements

Last but not least, there is data from the 5-point bow laser system. Figure 9 shows some the various signals we are analyzing for bow heave measurements, including IMU accelerations, velocities, displacements, pitch roll, and yaw. Note the phase lag between them. We are also using GPS velocities and displaements to refine the data. After these signals are appropriately processed down to an accurate heave measurement, we will subtract that from the laser range to get sea surface height. Power spectra are then computed from these results, and a 2D directional wave spectrum will be available.
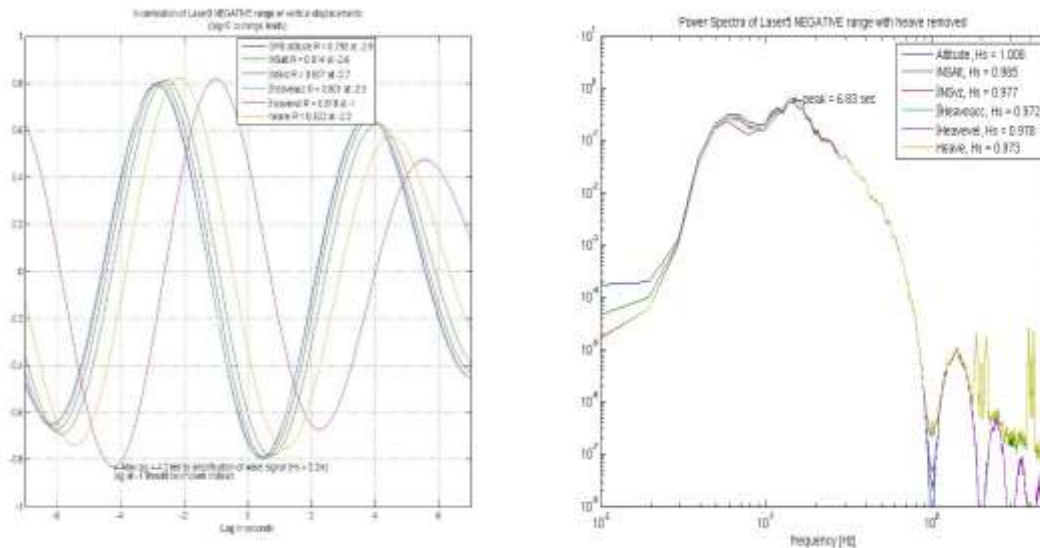
Figure 9. 5-point bow laser IMU signals (left), and resulting sea surface (wave) power spectra

RELATED PROJECTS

In-situ and Land-Based Remote Sensing of River Inlets and Their Interaction with Coastal Waters (RIVET I, New River Inlet, North Carolina)